US011609887B2

(12) **United States Patent**
Yamato et al.

(10) **Patent No.: US 11,609,887 B2**
(45) **Date of Patent: Mar. 21, 2023**

(54) **QUALITY CHECK APPARATUS, QUALITY CHECK METHOD, AND PROGRAM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 162 days.

(21) Appl. No.: **16/961,953**

(22) PCT Filed: **Nov. 29, 2018**

(86) PCT No.: **PCT/JP2018/043926**
§ 371 (c)(1),
(2) Date: **Jul. 14, 2020**

(87) PCT Pub. No.: **WO2019/159484**
PCT Pub. Date: **Aug. 22, 2019**

(65) **Prior Publication Data**

US 2020/0379962 A1 Dec. 3, 2020

(30) **Foreign Application Priority Data**

Feb. 13, 2018 (JP) JP2018-022956

(51) **Int. Cl.**
G06F 16/00 (2019.01)
G06F 16/215 (2019.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06F 16/215*** (2019.01); ***G06F 11/3089*** (2013.01); ***G06F 16/24565*** (2019.01);
(Continued)

(58) **Field of Classification Search**
CPC G06F 16/215; G06F 16/24565; G06F 16/383; G06F 16/9035; G06F 16/907;
(Continued)

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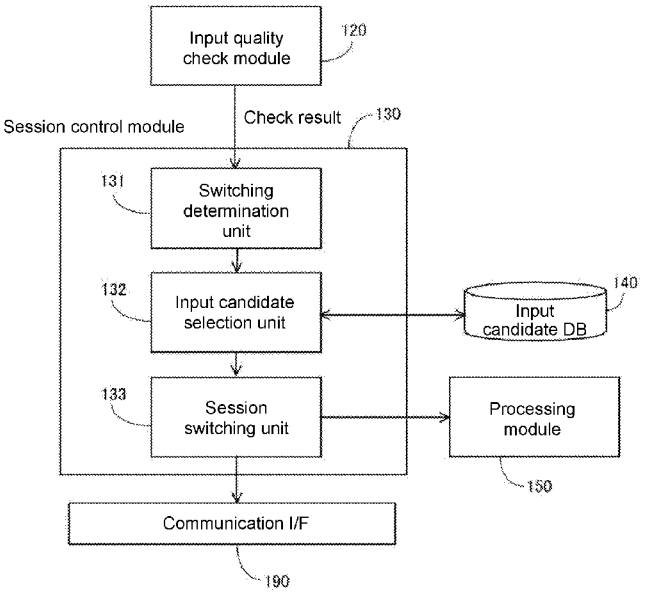
(57) **ABSTRACT**

A quality check apparatus, a quality check method, and a quality check program can check the quality of input data output to a processing module. A device outputs the input data and first metadata indicating an attribute regarding the quality of the input data to the processing module. The quality check apparatus includes a first obtaining unit and a check unit. The first obtaining unit obtains the first metadata. The check unit checks the quality of the input data based on the first metadata.

14 Claims, 15 Drawing Sheets



(51) **Int. Cl.**

G06F 16/907	(2019.01)
G06F 11/30	(2006.01)
G06F 16/2455	(2019.01)
G06F 16/383	(2019.01)
H04L 67/12	(2022.01)

(52) **U.S. Cl.**
CPC ***G06F 16/383*** (2019.01); ***G06F 16/907*** (2019.01); *H04L 67/12* (2013.01)

(58) **Field of Classification Search**
CPC G06F 11/3089; H04Q 2209/10; H04Q 2209/40; H04Q 2209/70; H04Q 9/00; G08C 15/00; G16Y 40/20; G01D 21/00; H04L 67/12
See application file for complete search history.

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FIG. 1

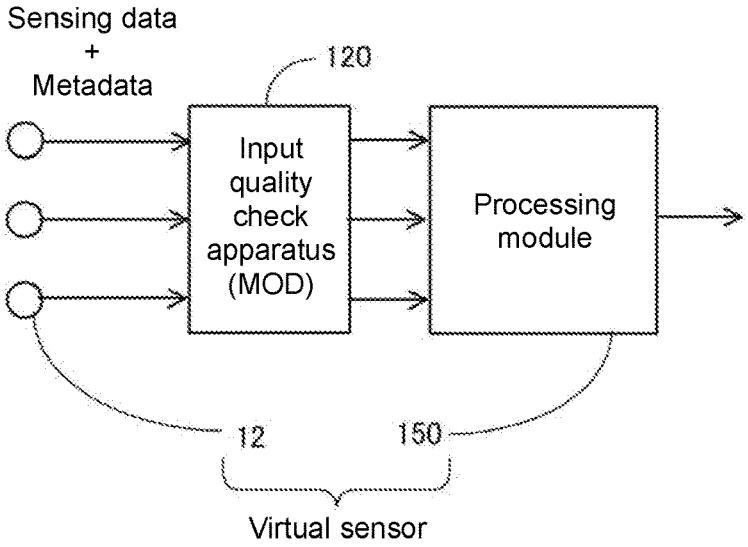

Sensing data
+
Metadata
120
Input quality check apparatus (MOD)
Processing module
12
150
Virtual sensor

FIG. 2

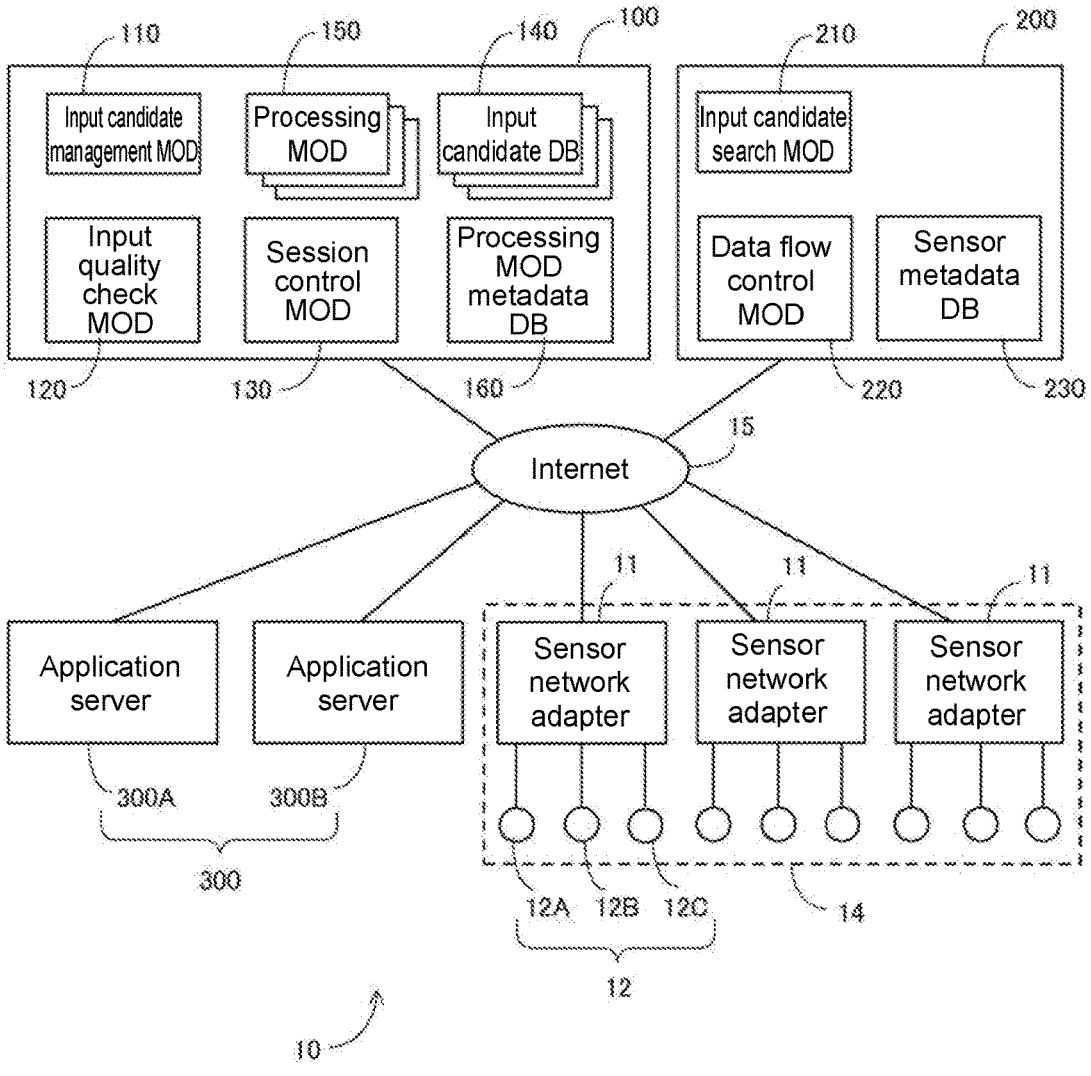

110
150
140
100
210
200
Input candidate management MOD
Processing MOD
Input candidate DB
Input candidate search MOD
Input quality check MOD
Session control MOD
Processing MOD metadata DB
Data flow control MOD
Sensor metadata DB
120
130
160
220
230
15
Internet
11
11
11
Application server
Application server
Sensor network adapter
Sensor network adapter
Sensor network adapter
300A
300B
300
12A
12B
12C
14
12
10

FIG. 3

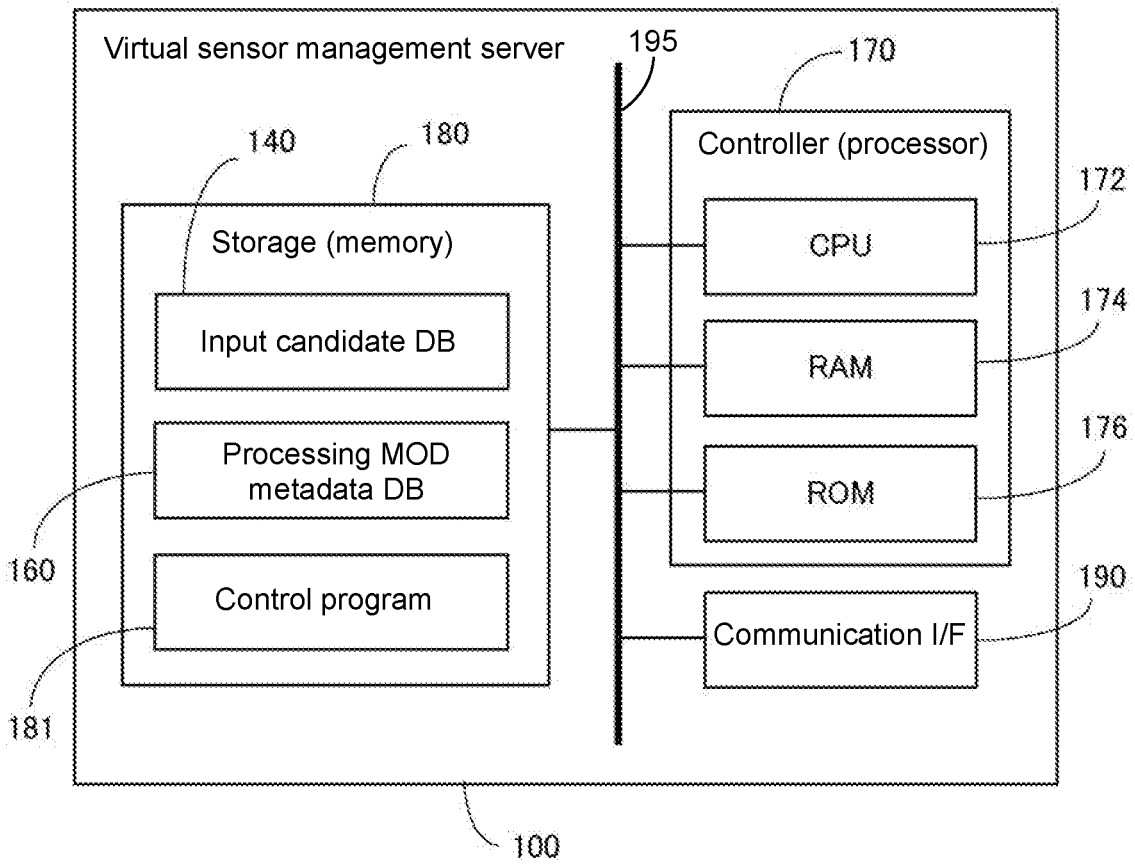


FIG. 4

Input candidate DB

ID:M1 ID:M2 ID:M3

Port number	Candidate 1	Candidate 2	Candidate 3
1	Sensor A1	Sensor A2	Sensor A3
2	Sensor B1	Sensor B2	Sensor B3
3	Sensor C1	Sensor C2	Sensor C3

140

FIG. 5

Processing module metadata DB

Processing module ID	Port number	Processing module metadata							
		Basic conditions				Quality conditions			
		Class	Target	Location	...	Outlier	Data dropout frequency	Manufacturer	...
M1	1	Temp. sensor	Outside temp.	P1	...	≤ 5%	≤ 1%	Any	...
	2	Temp. sensor	Outside temp.	P2	...	≤ 5%	≤ 1%	Any	...
	3	Temp. sensor	Outside temp.	P3	...	≤ 5%	≤ 1%	Any	...
M2	1	Camera	Station ticket gate	Any	...	≤ 0.1%	≤ 0.1%	Company O or P	...
	2	Illumination sensor	Illumination	Any	...	≤ 0.1%	≤ 0.1%	Excluding company M	...
	3	Temp. sensor	Temperature	Any	...	≤ 0.1%	≤ 0.1%	Company O or P	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

160

FIG. 6

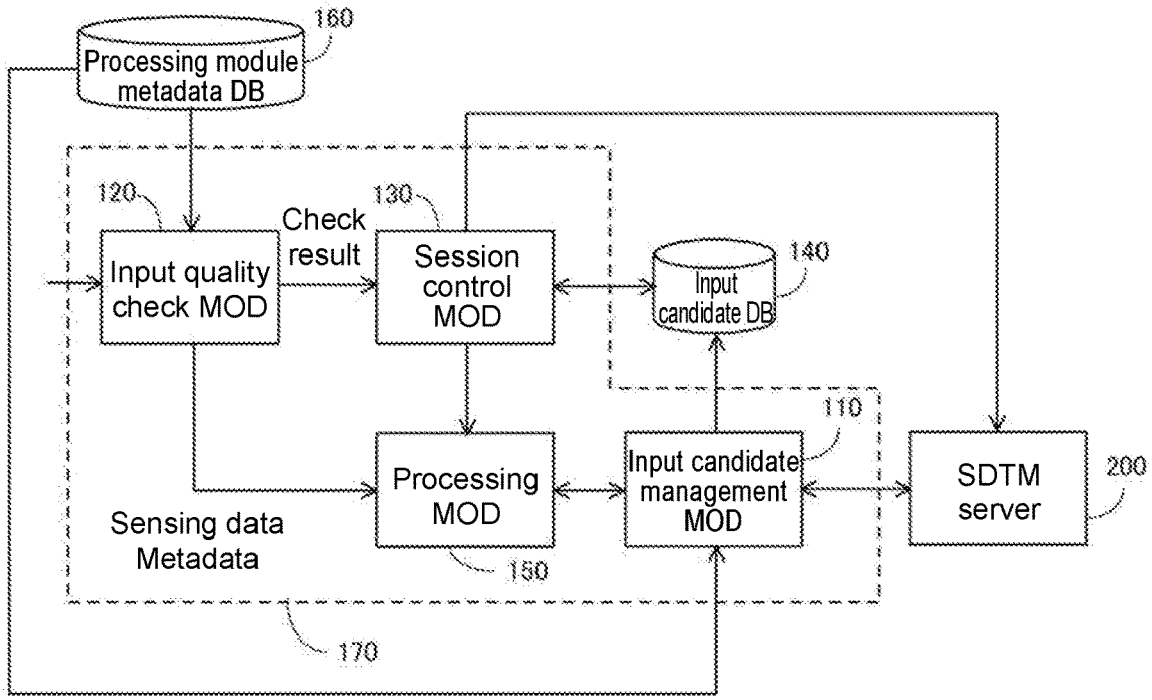

160
Processing module metadata DB
120
Input quality check MOD
Check result
130
Session control MOD
140
Input candidate DB
110
Input candidate management MOD
SDTM server
200
Processing MOD
Sensing data
Metadata
150
170

FIG. 7

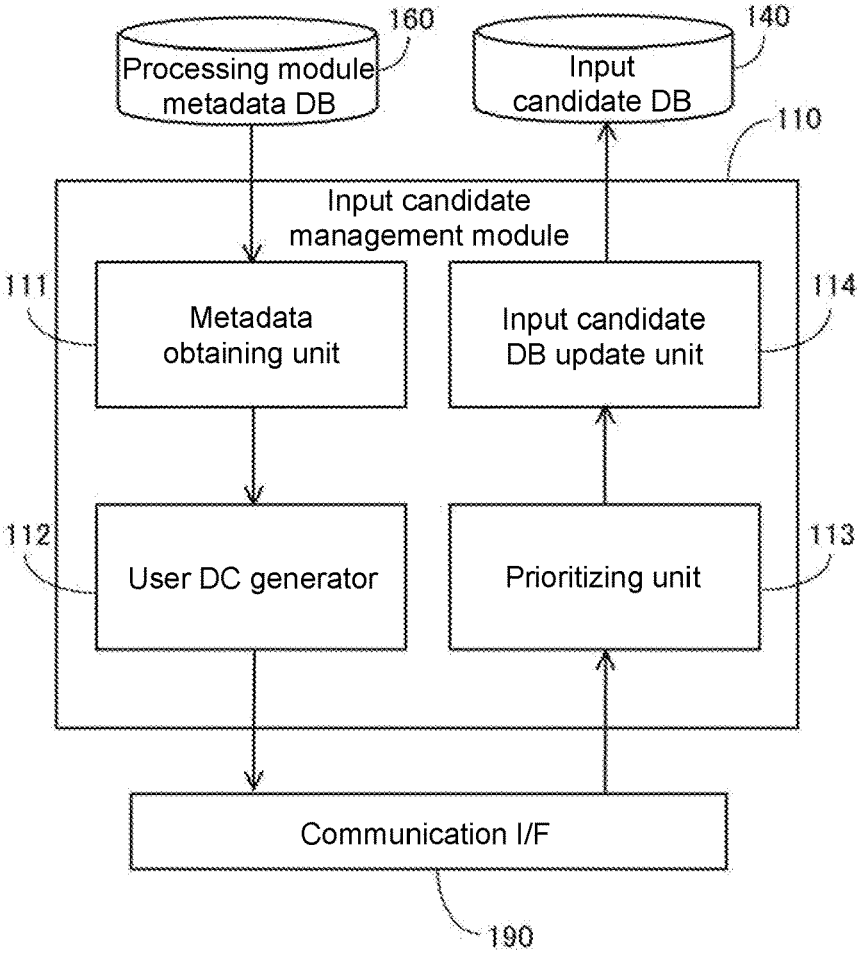

160
Processing module metadata DB
140
Input candidate DB
110
Input candidate management module
111
Metadata obtaining unit
114
Input candidate DB update unit
112
User DC generator
113
Prioritizing unit
Communication I/F
190

FIG. 8

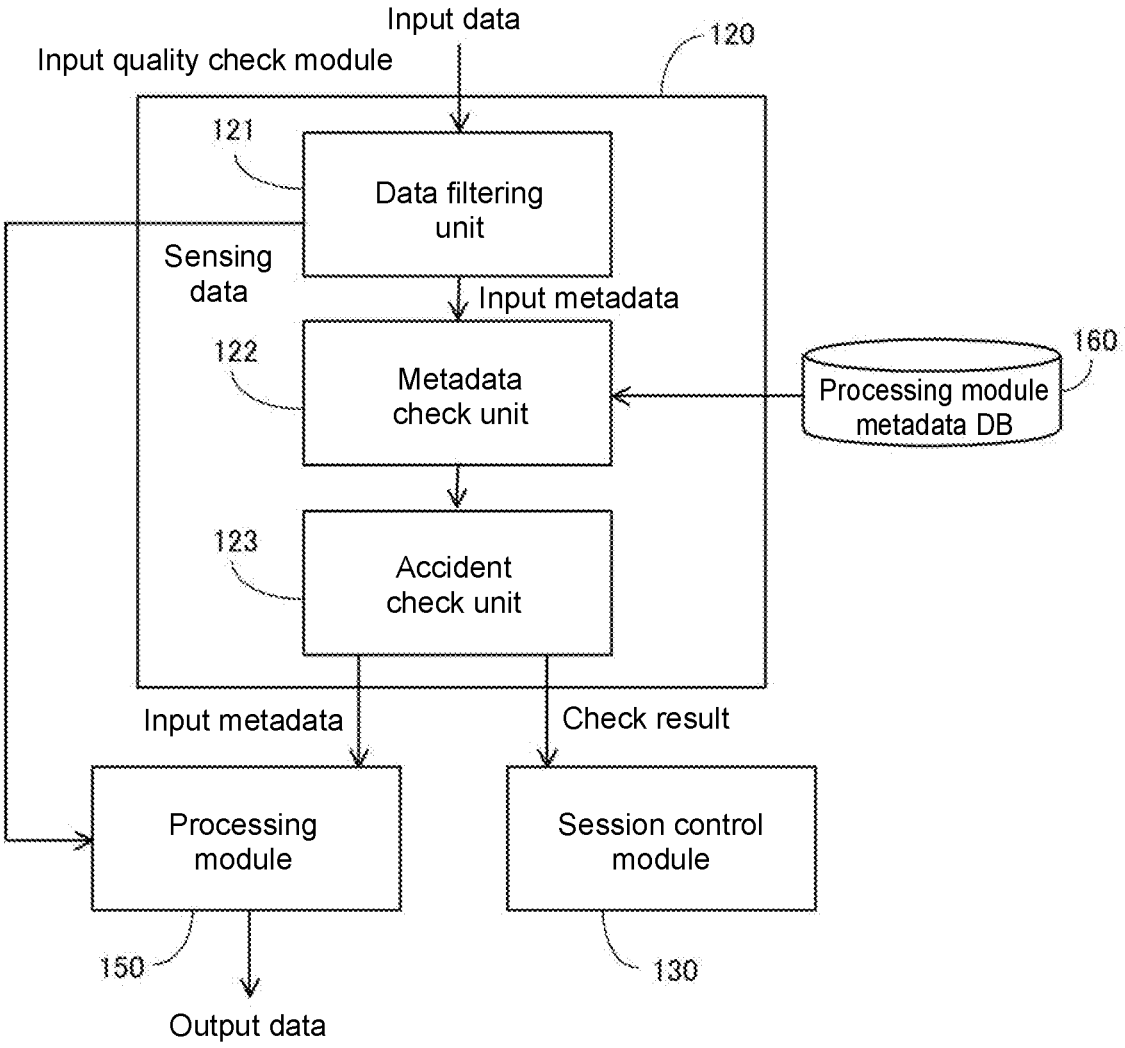

Input data
Input quality check module
120
121
Data filtering unit
Sensing data
Input metadata
122
Metadata check unit
160
Processing module metadata DB
123
Accident check unit
Input metadata
Check result
Processing module
Session control module
150
130
Output data

FIG 9

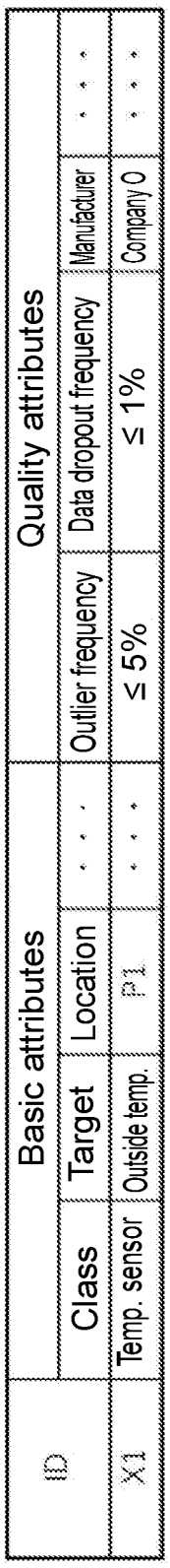

ID
Basic attributes
Class
Target
Location
Quality attributes
Outlier frequency
Data dropout frequency
Manufacturer
X1
Temp. sensor
Outside temp.
P1
≤ 5%
≤ 1%
Company 0
60

FIG. 10

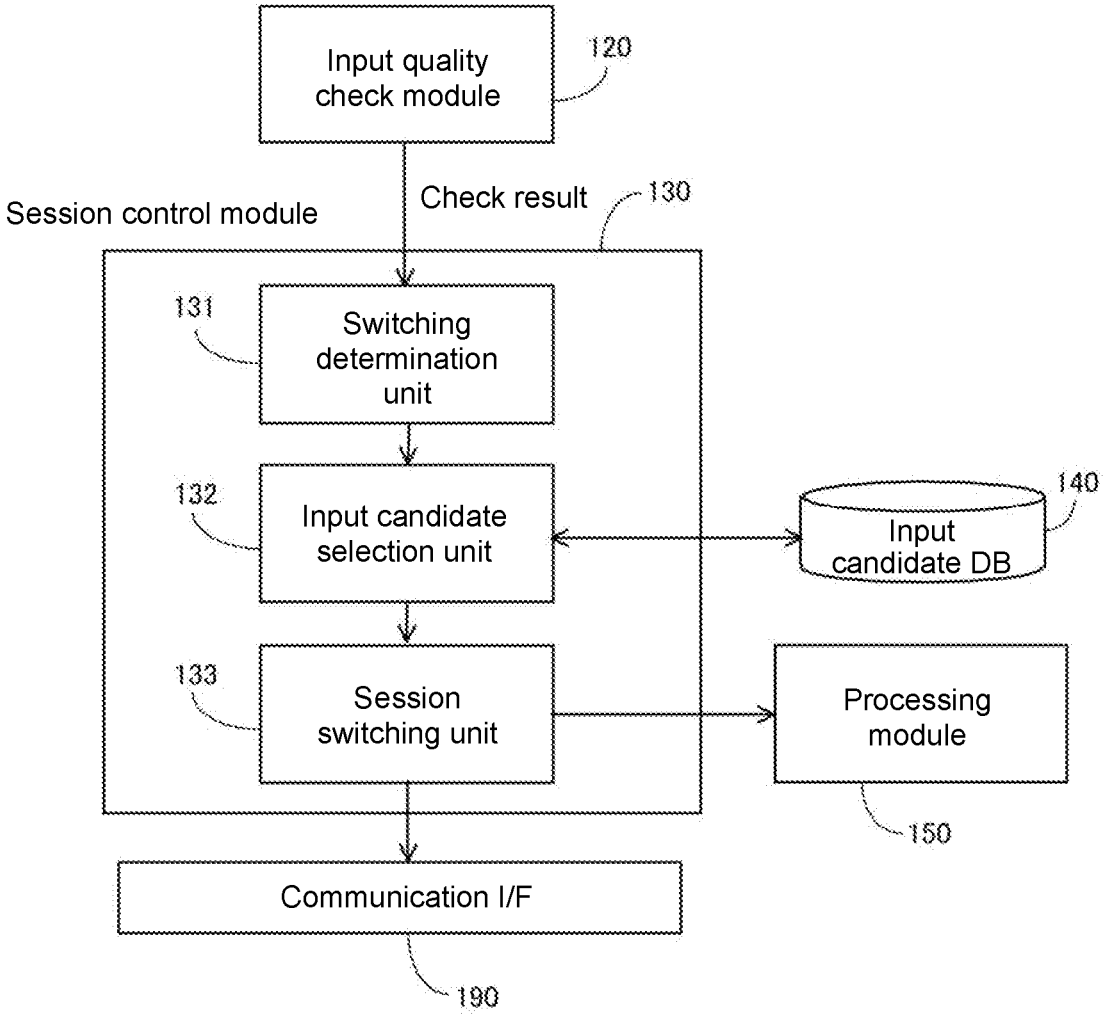

Input quality check module
120
Session control module
Check result
130
131
Switching determination unit
132
Input candidate selection unit
140
Input candidate DB
133
Session switching unit
Processing module
150
Communication I/F
190

FIG. 11

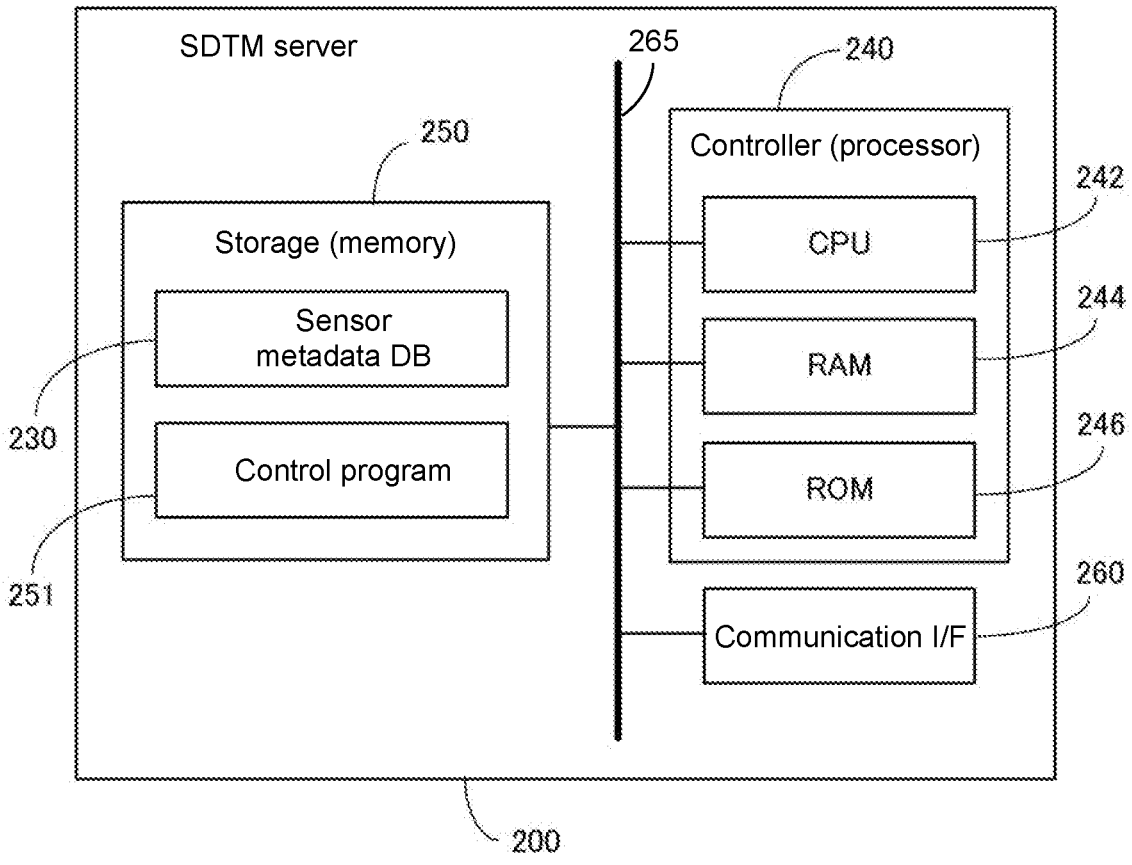

SDTM server
265
240
250
Controller (processor)
242
Storage (memory)
CPU
244
Sensor
metadata DB
RAM
230
246
Control program
ROM
251
260
Communication I/F
200

FIG. 12

Sensor metadata DB

Sensor ID	Sensor metadata						
	Basic attributes				Quality attributes		
	Class	Target	Location	・・・	Outlier frequency	Data dropout frequency	Manufacturer	・・・
1	Temp. sensor	Outside temp.	P1	・・・	≤ 5%	≤ 1%	Company O	・・・
2	Camera	Station ticket gate	P2	・・・	≤ 0.1%	≤ 0.1%	Company P	・・・
3	Illumination sensor	Illumination	P3	・・・	≤ 0.1%	≤ 0.1%	Company M	・・・
4	Temp. sensor	Temperature	P4	・・・	≤ 0.1%	≤ 0.1%	Company O	・・・
・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・

230

FIG. 13

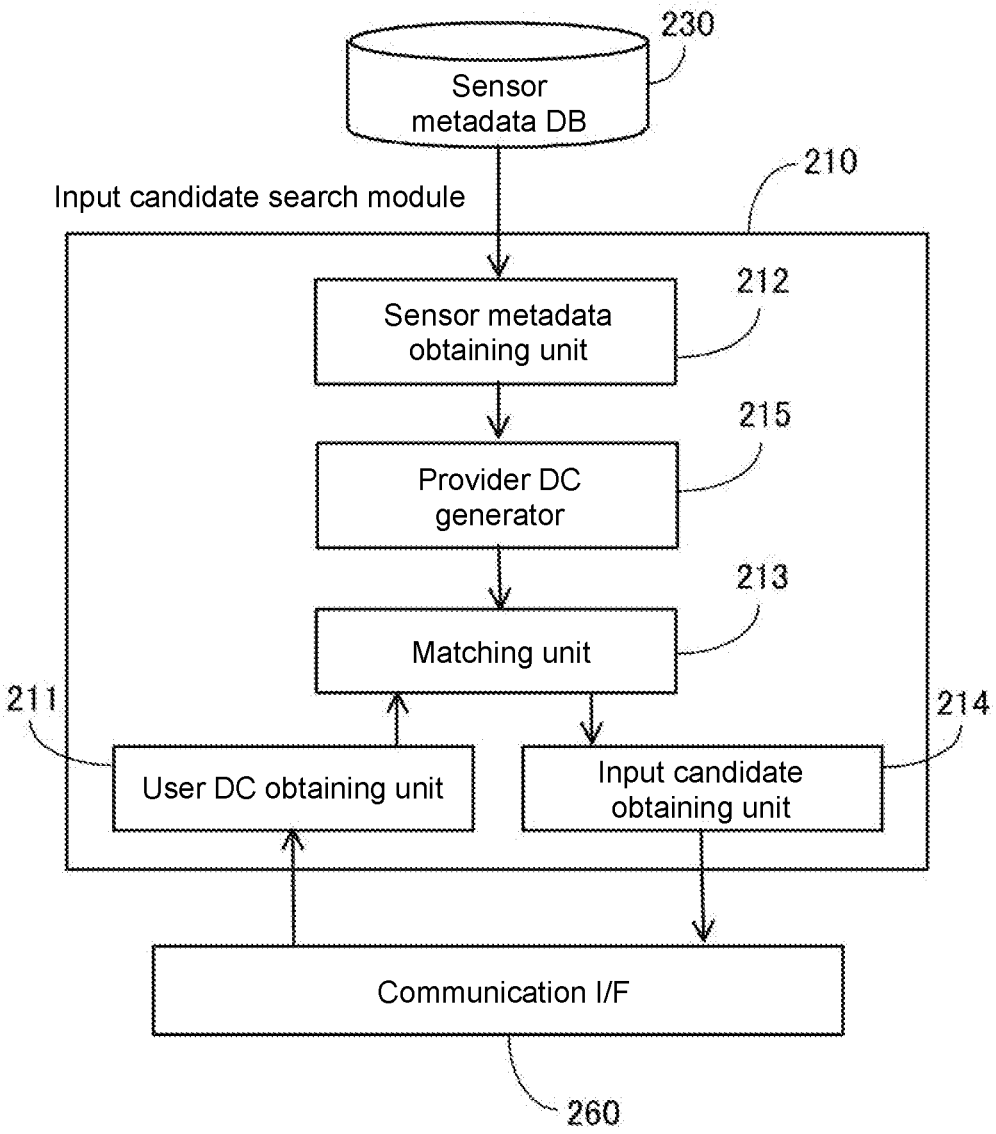

230
Sensor metadata DB
210
Input candidate search module
212
Sensor metadata obtaining unit
215
Provider DC generator
213
Matching unit
211
User DC obtaining unit
214
Input candidate obtaining unit
Communication I/F
260

FIG. 14

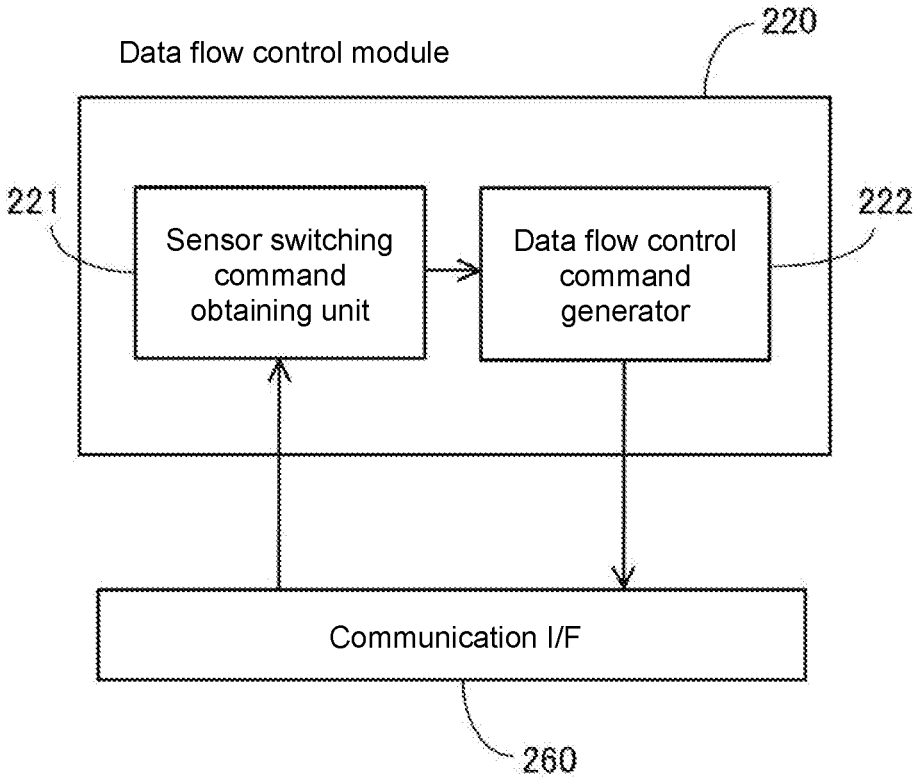

Data flow control module
220
221
Sensor switching command obtaining unit
Data flow control command generator
222
Communication I/F
260

FIG. 15

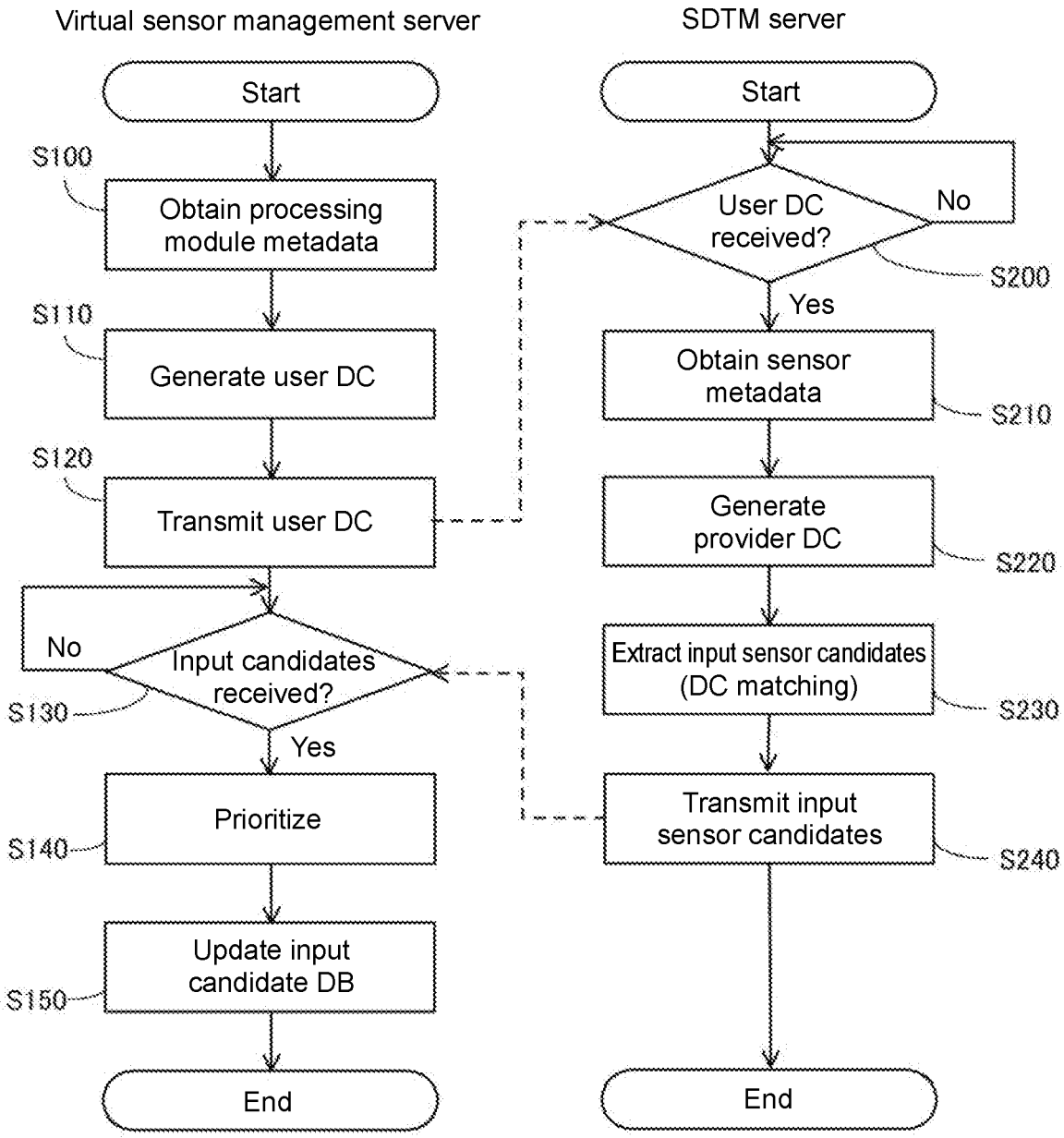

Virtual sensor management server
SDTM server
Start
S100
Obtain processing module metadata
S110
Generate user DC
S120
Transmit user DC
No
Input candidates received?
S130
Yes
Prioritize
S140
Update input candidate DB
S150
End
Start
User DC received?
No
S200
Yes
Obtain sensor metadata
S210
Generate provider DC
S220
Extract input sensor candidates (DC matching)
S230
Transmit input sensor candidates
S240
End

FIG. 16

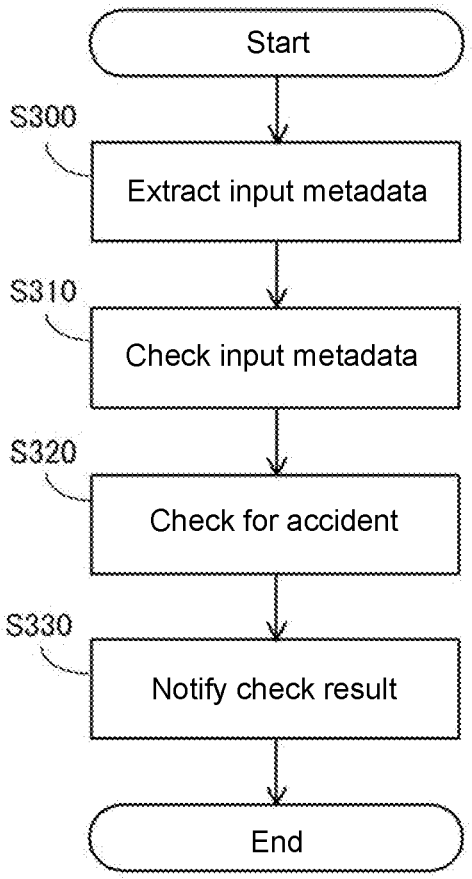

Start
S300
Extract input metadata
S310
Check input metadata
S320
Check for accident
S330
Notify check result
End

FIG. 17

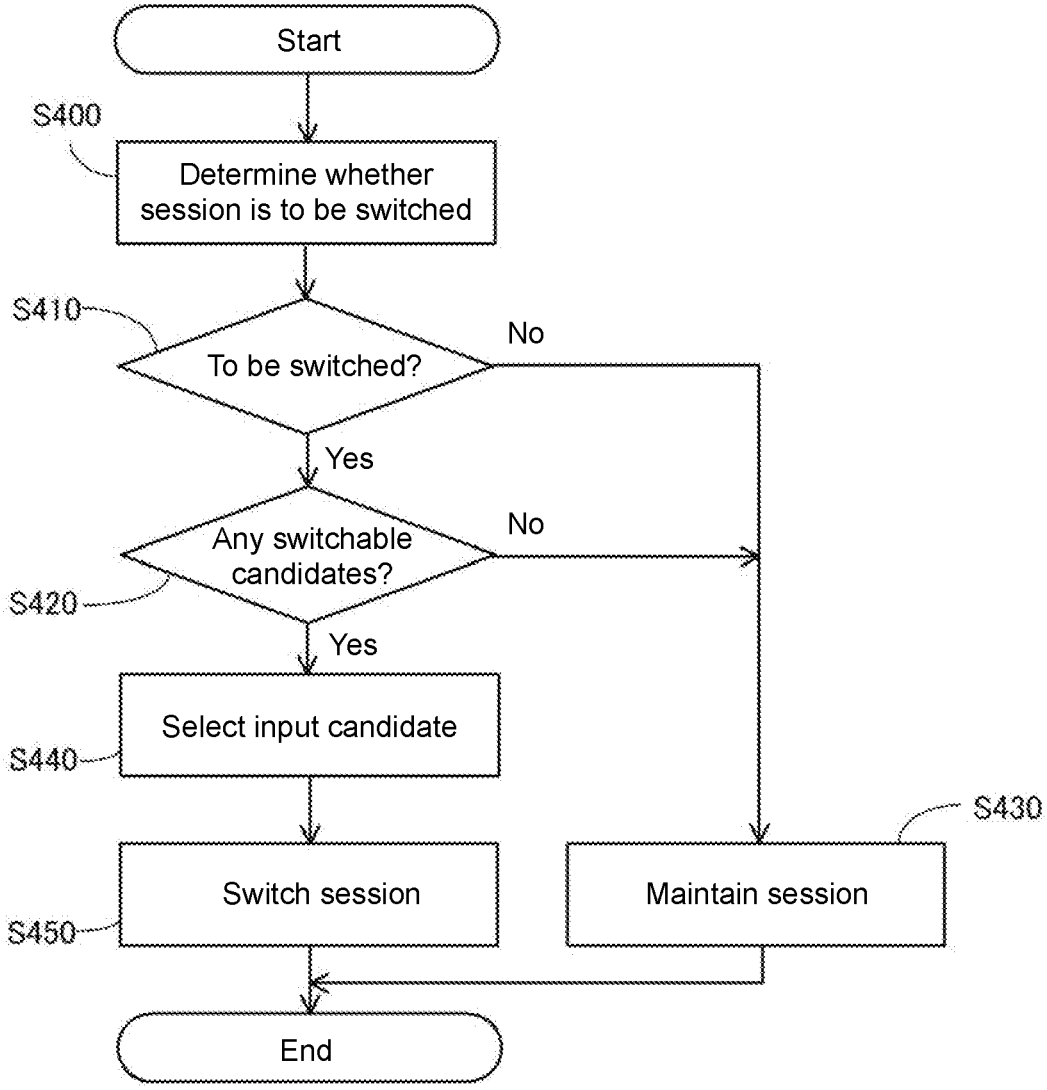
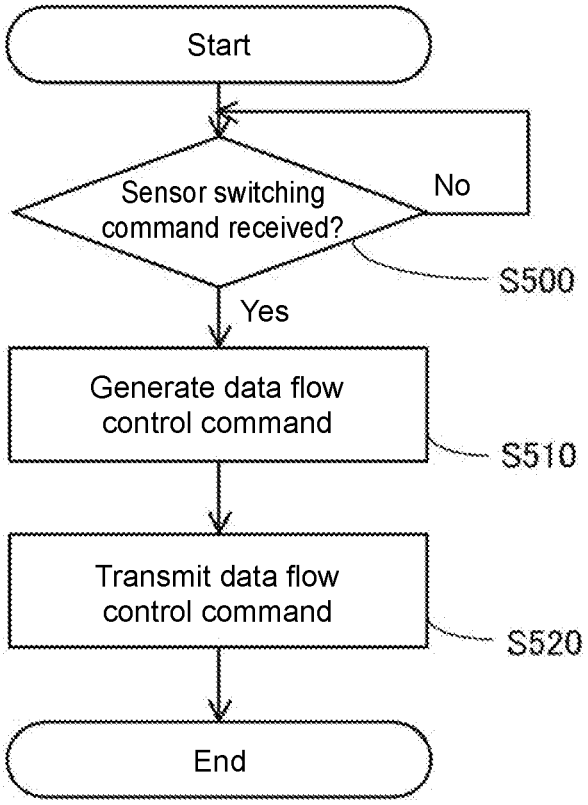

Start
S400
Determine whether session is to be switched
S410
To be switched?
No
Yes
Any switchable candidates?
No
S420
Yes
Select input candidate
S440
S430
Switch session
Maintain session
S450
End

FIG. 18


Start
Sensor switching command received?
No
S500
Yes
Generate data flow control command
S510
Transmit data flow control command
S520
End

QUALITY CHECK APPARATUS, QUALITY CHECK METHOD, AND PROGRAM

FIELD

The present invention relates to a quality check apparatus, a quality check method, and a quality check program.

BACKGROUND

Japanese Unexamined Patent Application Publication No. 2014-45242 (Patent Literature 1) describes a virtual sensor generation apparatus that generates a virtual sensor. This virtual sensor generation apparatus detects a real sensor located within a predetermined range and generates a virtual sensor using the detected real sensor (refer to Patent Literature 1).

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2014-45242

SUMMARY

Technical Problem

The virtual sensor described in Patent Literature 1 includes, for example, a real sensor (an example of a device) and a processing module. The processing module processes sensing data (an example of input data) output from the real sensor to generate output data different from the input data. To implement a virtual sensor having an intended function, for example, the quality of input data output to the processing module is to be maintained and thus to be checked to maintain intended quality. However, Patent Literature 1 does not describe any method for checking the quality of input data.

In response to the above issue, one or more aspects of the present invention are directed to a quality check apparatus, a quality check method, and a quality check program for checking the quality of input data output to a processing module.

Solution to Problem

A quality check apparatus according to one aspect of the present invention is an apparatus for checking a quality of input data output from a device to a processing module. The device outputs the input data and first metadata indicating an attribute regarding the quality of the input data to the processing module. The processing module generates, based on at least one piece of the input data, output data different from the at least one piece of input data. The quality check apparatus includes a first obtaining unit and a check unit. The first obtaining unit obtains the first metadata. The check unit checks the quality of the input data based on the first metadata.

In this quality check apparatus, the first metadata output from the device indicates the attribute regarding the quality of input data. The quality of the input data is checked based on the first metadata. The quality check apparatus can thus check the quality of input data.

In the above quality check apparatus, the processing module may be associated with second metadata indicating a condition regarding the quality of the input data. The quality check apparatus may further include a second obtaining unit that obtains the second metadata. The check unit may check whether the attribute regarding the quality of the input data indicated by the first metadata satisfies the condition regarding the quality of the input data indicated by the second metadata.

This quality check apparatus checks whether the attribute regarding the quality of input data indicated by the first metadata satisfies the condition regarding the quality of input data indicated by the second metadata. The quality check apparatus can thus check whether the quality of input data satisfies the condition regarding the quality of input data output to the processing module.

In the above quality check apparatus, the device may be a sensor. The input data may be sensing data generated by the sensor.

In the above quality check apparatus, the processing module may generate the output data based on a plurality of pieces of the input data.

In the above quality check apparatus, the processing module may switch the device that outputs the input data to the processing module.

In the above quality check apparatus, the processing module and the device that outputs the input data to the processing module may form a virtual sensor.

A quality check apparatus according to another aspect of the present invention is an apparatus for checking a quality of at least one data set to be input into a processing module. The at least one data set includes a plurality of pieces of data and metadata indicating an attribute regarding a quality of each of the plurality of pieces of data. The processing module generates, based on at least one piece of input data, output data different from the at least one piece of input data when the at least one data set is input. The quality check apparatus includes an obtaining unit and a check unit. The obtaining unit obtains the metadata. The check unit checks the quality of the at least one data set based on the metadata.

In this quality check apparatus, the metadata included in the data set indicates the attribute regarding the quality of data included in the data set. The quality of the data set is checked based on the metadata. The quality check apparatus can thus check the quality of a data set.

A quality check method according to still another aspect of the present invention is a method for checking a quality of input data output from a device to a processing module. The device outputs the input data and first metadata indicating an attribute regarding the quality of the input data to the processing module. The processing module generates, based on at least one piece of the input data, output data different from the at least on piece of input data. The quality check method includes obtaining the first metadata, and checking the quality of the input data based on the first metadata.

With this quality check method, the first metadata output from the device indicates the attribute regarding the quality of input data. The quality of the input data is checked based on the first metadata. The quality check method can thus check the quality of input data.

A program according to still another aspect of the present invention causes a computer to implement checking a quality of input data output from a device to a processing module. The device outputs the input data and first metadata indicating an attribute regarding the quality of the input data to the processing module. The processing module generates, based on at least one piece of the input data, output data different from the at least one piece of input data. The

program causes the computer to implement obtaining the first metadata, and checking the quality of the input data based on the first metadata.

This program is executed by the computer to cause the first metadata output from the device to indicate the attribute regarding the quality of input data. The quality of the input data is checked based on the first metadata. The program can thus check the quality of input data.

Advantageous Effects

The quality check apparatus, the quality check method, and the quality check program according to the aspects of the present invention can check the quality of input data output to the processing module.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an input quality check apparatus.

FIG. **2** is a diagram showing an example sensor network system.

FIG. **3** is a diagram of a virtual sensor management server showing its example hardware configuration.

FIG. **4** is a diagram showing an example input candidate database (DB).

FIG. **5** is a table showing an example processing module metadata DB.

FIG. **6** is a diagram showing an example relationship between software modules implemented by a controller.

FIG. **7** is a diagram of an input candidate management module showing its detailed example configuration.

FIG. **8** is a diagram of an input quality check module showing its detailed example configuration.

FIG. **9** is a table showing example metadata associated with sensing data.

FIG. **10** is a diagram of a session control module showing its detailed example configuration.

FIG. **11** is a diagram of a sensing data trading market (SDTM) server showing its example hardware configuration.

FIG. **12** is a table showing an example sensor metadata DB.

FIG. **13** is a diagram of an input candidate search module showing its detailed example configuration.

FIG. **14** is a diagram of a data flow control module showing its detailed example configuration.

FIG. **15** is a flowchart showing an example operation of extracting input sensor candidates for a processing module.

FIG. **16** is a flowchart showing an example operation of checking the quality of input data output to the processing module.

FIG. **17** is a flowchart showing an example operation of switching a session between the processing module and a real sensor.

FIG. **18** is a flowchart showing an example of a data flow control operation.

DETAILED DESCRIPTION

One or more embodiments of the present invention (hereafter, the present embodiment) will now be described in detail with reference to the drawings. The same or corresponding components in the figures are given the same reference numerals, and will not be described repeatedly. The present embodiment described below is a mere example of the present invention in all aspects. The present embodiment may be variously modified or altered within the scope of the present invention. More specifically, the present invention may be implemented as appropriate using any configuration specific to each embodiment.

1. OVERVIEW

FIG. **1** is a schematic diagram of an input quality check apparatus (module) **120** according to the present embodiment. Referring to FIG. **1**, a processing module **150** includes multiple input ports. Each input port receives sensing data (an example of input data) output from a real sensor **12** (an example of a device). Based on input data, the processing module **150** generates output data different from the input data. In other words, the processing module **150** and the real sensors **12** (input sensors) that output input data to the processing module **150** form a virtual sensor. The virtual sensor is a sensor module that outputs, based on sensing data resulting from the input sensor observing a target, the observation results of a target different from the target observed by the input sensor as sensing data. The virtual sensor will be described in detail later.

To implement a virtual sensor having an intended function, the quality of input data output to the processing module **150** is to be maintained and thus to be checked to maintain intended quality. The input quality check apparatus **120** according to the present embodiment checks the quality of input data output to the processing module **150**.

More specifically, the real sensors **12** output sensing data and input metadata indicating an attribute regarding the quality of the sensing data. The input metadata will be described in detail later. The input quality check apparatus **120** is located between the real sensors **12** and the input ports of the processing module **150**. The input quality check apparatus **120** checks the quality of sensing data output from the real sensor **12** based on input metadata output from the real sensor **12**.

Thus, the input quality check apparatus **120** checks the quality of sensing data to be input into the processing module **150** by referring to the input metadata. The specific configuration and operations will be described one after another.

2. EXAMPLE CONFIGURATION

2-1. Example Configuration of Entire System

FIG. **2** is a diagram showing an example sensor network system **10** including the input quality check module (apparatus) **120** according to the present embodiment. In the example in FIG. **2**, the sensor network system **10** includes a sensor network unit **14**, a virtual sensor management server **100**, a sensing data trading market (SDTM) server **200**, and application servers **300**.

The sensor network unit **14**, the virtual sensor management server **100**, the SDTM server **200**, and the application servers **300** are connected to one another through the Internet **15** to allow communication between them. The sensor network system **10** may include either more or fewer components (including the virtual sensor management server **100**, the SDTM server **200**, the application servers **300**, sensor network adapters **11**, and the real sensors **12**) than the components shown in FIG. **2**.

In the sensor network system **10**, sensing data generated by sensing devices (such as real sensors and virtual sensors) can be distributed. For example, sensing data generated by the real sensors **12** can be distributed to the virtual sensor

management server **100**, and sensing data generated by the virtual sensors can be distributed to the application servers **300**.

The sensor network unit **14** includes, for example, multiple sensor network adapters **11**. Each sensor network adapter **11** is connected to multiple real sensors **12**. The real sensors **12** are connected to the Internet **15** through each sensor network adapter **11**.

Each real sensor **12** observes a target to obtain sensing data. Each real sensor **12** may be an image sensor (camera), a temperature sensor, a humidity sensor, an illumination sensor, a force sensor, a sound sensor, a radio frequency identification (RFID) sensor, an infrared sensor, a posture sensor, a rain sensor, a radiation sensor, or a gas sensor. Each real sensor **12** may be any other sensor. Each real sensor **12** may be a stationary sensor, or a mobile sensor, such as a mobile phone, a smartphone, or a tablet. Each real sensor **12** may be a single sensing device, or may include multiple sensing devices. The real sensors **12** may be installed for any purposes. For example, the real sensors **12** may be installed for factory automation (FA) and production management at a factory, urban traffic control, weather or other environmental measurement, healthcare, or crime prevention.

In the sensor network unit **14**, the sensor network adapters **11** are located at different sites (remote from one another), and the real sensors **12** connected to each sensor network adapter **11** are located at the same site (or close sites). The sensor network adapters **11** and the real sensors **12** may be located in a different manner.

Each application server **300** (**300**A or **300**B) executes an application that uses sensing data, and is implemented by, for example, a general-purpose computer. The application server **300** obtains sensing data for use through the Internet **15**.

The virtual sensor management server **100** implements a virtual sensor. The virtual sensor management server **100** implements multiple processing modules **150**, an input candidate management module **110**, an input quality check module **120**, and a session control module **130**, and manages input candidate DBs **140** and a processing module metadata DB **160**. The multiple processing modules **150**, the input candidate management module **110**, the input quality check module **120**, and the session control module **130** are, for example, software modules.

Each processing module **150** includes at least one input port and generates output data different from input data input into the input port based on the input data. For example, the processing module **150** may output data representing the number of people in a room based on input data (audio data) output from a sound sensor installed in the room. In this case, the processing module **150** and the real sensor **12** (sound sensor) can implement a virtual sensor that detects the number of people in a room.

The input candidate management module **110** manages candidates for the real sensors **12** (hereafter also referred to as input sensor candidates) that output input data to the processing module **150**. The input quality check module **120** checks the quality of input data output to the processing module **150**. The session control module **130** controls sessions between the processing module **150** and the real sensors **12**.

When, for example, the input quality check module **120** determines that the quality of input data fails to satisfy predetermined criteria, the session control module **130** switches the input sensor for the processing module **150** to another one of input sensor candidates extracted in advance. Each software module and each database will be described in detail later.

The SDTM server **200** implements distribution of sensing data in the sensor network system **10**. The SDTM server **200** implements an input candidate search module **210** and a data flow control module **220**, and manages a sensor metadata DB **230**. The input candidate search module **210** and the data flow control module **220** are, for example, software modules.

The input candidate search module **210** searches for input sensor candidates for the processing module **150** in response to a request from the virtual sensor management server **100** (input candidate management module **110**). The data flow control module **220** controls, for example, distribution of sensing data from the real sensors **12** to the processing module **150** in response to a request from the virtual sensor management server **100** (session control module **130**). Each software module and each database will be described in detail later.

2-2. Example Hardware Configuration of Virtual Sensor Management Server

FIG. **3** is a diagram of the virtual sensor management server **100** showing its example hardware configuration. The virtual sensor management server **100** according to the present embodiment is implemented by, for example, a general-purpose computer.

In the example in FIG. **3**, the virtual sensor management server **100** includes a controller **170**, a communication interface (I/F) **190**, and a storage **180**. The components are electrically connected to one another with a bus **195**.

The controller **170** includes, for example, a central processing unit (CPU) **172**, a random-access memory (RAM) **174**, and a read-only memory (ROM) **176**. The controller **170** controls each unit in accordance with the information processing to be performed.

The communication I/F **190** communicates with external devices (e.g., the SDTM server **200**, the application servers **300**, and the sensor network unit **14** in FIG. **2**) external to the virtual sensor management server **100** through the Internet **15**. The communication I/F **190** includes, for example, a wired local area network (LAN) module and a wireless LAN module.

The storage **180** is an auxiliary storage device such as a hard disk drive or a solid-state drive. The storage **180** stores, for example, the input candidate DB **140**, the processing module metadata DB **160**, and a control program **181**.

FIG. **4** is a diagram showing an example input candidate DB **140**. Referring to FIG. **4**, the input candidate DB **140** manages input sensor candidates for the processing module **150**. In the input candidate DB **140**, input sensor candidates are managed for each input port of the processing module **150**. In this example, for an input port 2 of the processing module **150** (with an ID of M1), a sensor B1 is determined to be a first candidate, a sensor B2 is determined to be a second candidate, and a sensor B3 is determined to be a third candidate. Each input port may manage fewer than three input sensor candidates or four or more input sensor candidates.

As described in detail later, each input candidate DB **140** is repeatedly updated in predetermined cycles. When, for example, the specifications of each real sensor **12** included in the sensor network unit **14** are changed, input sensor candidates listed in the input candidate DB **140** are changed.

FIG. **5** is a table showing an example processing module metadata DB **160**. Referring to FIG. **5**, the processing module metadata DB **160** manages metadata indicating the conditions of input data output to the processing module **150**. The metadata of each processing module **150** implemented by the virtual sensor management server **100** is registered in advance with the processing module metadata DB **160**. The processing module metadata DB **160** manages metadata for each input port of the processing module **150**.

The processing module metadata includes, for example, basic conditions and quality conditions. The basic conditions are the conditions to be basically satisfied by each real sensor **12** that outputs input data (sensing data), including a class, an observation target, and an installation location.

The class refers to the type of the real sensor **12**. Examples of the class include a temperature sensor, an illumination sensor, and a camera. The observation target refers to a target to be observed by the real sensor **12**. Examples of the observation target include outside temperature, a station ticket gate, illumination, and temperature. The installation location refers to the location where the real sensor **12** is installed. Examples of the installation location include positions P1, P2, and P3 (P1, P2, and P3 indicate specific positions such as Kyoto Station Area).

The quality conditions relate to the quality of input data (sensing data). Examples of the conditions include an outlier condition, a data dropout frequency condition, and a manufacturer condition. Besides these, the quality conditions may also include a sensor state condition, a sensor installation condition, a sensor maintenance history condition, a data specification condition, and a data resolution condition.

The outlier condition relates to the probability that the input data output from the real sensor **12** falls in a range of outliers. The data dropout frequency condition relates to the probability that data fails to be input into an input port at an intended time. The manufacturer condition relates to a manufacturer of the real sensor **12** that outputs the input data.

The sensor state condition relates to the state of the real sensor **12** that outputs the input data. Examples of the sensor state condition include the sensor to be acceptable when operating, and the sensor to be unacceptable after deteriorating to a predetermined level even partially. The sensor installation condition relates to the installation of the real sensor **12** that outputs the input data. Examples of the sensor installation condition include the sensor to be unacceptable when deviating from the initial installation position and the sensor to be acceptable when remaining without falling from the initial installation position. The sensor maintenance history condition relates to the maintenance history of the real sensor **12** that outputs the input data. Examples of the sensor maintenance history condition include the sensor maintenance to be unacceptable when the frequency of maintenance inspection is less than once per day and the sensor maintenance to be acceptable when the frequency of maintenance inspection is equal to or more than once per month. The data specification condition relates to the specifications of the input data. The data resolution condition relates to the resolution of the input data.

Referring back to FIG. **3**, the control program **181** is used for the virtual sensor management server **100** and is executed by the controller **170**. For example, modules such as the processing modules **150**, the input candidate management module **110**, the input quality check module **120**, and the session control module **130** (FIG. **2**) may be implemented by the controller **170** executing the control program **181**. When the controller **170** executes the control program **181**, the control program **181** is loaded into the RAM **174**. The CPU **172** in the controller **170** then interprets and executes the control program **181** loaded in the RAM **174** to control each unit. Each software module implemented by the controller **170** in accordance with the control program **181** will be described.

2-3. Example Software Configuration of Virtual Sensor Management Server

FIG. **6** is a diagram showing an example relationship between the software modules implemented by the controller **170**. In the example in FIG. **6**, the controller **170** implements the processing module **150**, the input candidate management module **110**, the input quality check module **120**, and the session control module **130**.

Referring to the processing module metadata DB **160**, the input candidate management module **110** extracts the real sensors **12** suitable for the input sensors for the processing module **150** in cooperation with the SDTM server **200**. The extracted input sensor candidates are managed in the input candidate DB **140**.

Referring to the processing module metadata DB **160**, the input quality check module **120** checks whether the quality of data currently input into the processing module **150** satisfies the conditions of input data output to the processing module **150**.

The session control module **130** determines whether the input sensor for the processing module **150** is to be switched based on the check results of the input quality check module **120**. When determining that the input sensor is to be switched, the session control module **130** switches the input sensor to any of the real sensors **12** managed in the input candidate DB **140**.

The input candidate management module **110**, the input quality check module **120**, and the session control module **130** will be described one after another in detail.

2-3-1. Input Candidate Management Module

FIG. **7** is a diagram of the input candidate management module **110** showing its detailed example configuration. In the example in FIG. **7**, the input candidate management module **110** includes a metadata obtaining unit **111**, a user data catalogue generator **112**, a prioritizing unit **113**, and an input candidate DB update unit **114**. The input candidate management module **110** extracts input sensor candidates for each input port of the processing module **150**. Input sensor candidates for each input port may be extracted in parallel or in sequence. The modules will be described below using one input port of each processing module **150**.

The metadata obtaining unit **111** obtains, from the processing module metadata DB **160**, processing module metadata **161** (FIG. **1**) associated with the input port for which input sensor candidates are to be extracted.

The user data catalogue generator **112** generates a user data catalogue based on the processing module metadata **161** obtained by the metadata obtaining unit **111**. The user data catalogue lists the attributes of the real sensor **12** to be used by a user (virtual sensor management server **100**). The user data catalogue contains the conditions of input data indicated by the processing module metadata **161**. For example, the user data catalogue contains the basic conditions and the quality conditions of the input data.

The user data catalogue generated by the user data catalogue generator **112** is transmitted to the SDTM server **200** through the communication I/F **190**. As described in detail

later, the SDTM server **200** extracts the real sensor **12** satisfying the conditions listed in the user data catalogue. The SDTM server **200** receives information that can identify the extracted real sensor **12** (hereafter also referred to as real sensor information) through the communication I/F **190**. The real sensor information includes, for example, information indicating an IP address allocated to each real sensor **12** (information indicating the location of the real sensor **12** on the Internet **15**) and the attributes of the real sensor **12**.

When multiple pieces of real sensor information are received, the prioritizing unit **113** prioritizes the real sensors **12**. The prioritizing unit **113** may prioritize each of the real sensors **12** with any criterion. When, for example, the outlier condition is prioritized among the conditions contained in the user data catalogue, the prioritizing unit **113** may assign a higher priority to the real sensor **12** having a lower outlier frequency.

The input candidate DB update unit **114** updates the input candidate DB **140** (FIG. **4**) in accordance with the priority assigned by the prioritizing unit **113**. Thus, the input candidate DB **140** manages the real sensors **12** that satisfy the conditions listed in the user data catalogue in advance as input sensor candidates.

2-3-2. Input Quality Check Module

FIG. **8** is a diagram of the input quality check module **120** showing its detailed example configuration. In the example in FIG. **8**, the input quality check module **120** includes a data filtering unit **121**, a metadata check unit **122**, and an accident check unit **123**. The input data output from the real sensor **12** contains sensing data and metadata associated with the sensing data (hereafter also referred to as input metadata). The sensing data is generated by the real sensor **12** observing a target. The input metadata indicates the attributes of the sensing data generated by the real sensor **12**.

FIG. **9** is a table showing example input metadata **60** associated with sensing data. In the example in FIG. **9**, the input metadata **60** contains basic attributes and quality attributes. The basic attributes are the basic attributes of the real sensor **12** that outputs the input data, including a class, an observation target, and an installation location.

The quality attributes relate to the quality of sensing data, including an outlier frequency, a data dropout frequency, and the manufacturer of each real sensor **12**. The quality attributes may further include a sensor state attribute, a sensor installation attribute, a sensor maintenance history attribute, a data specification attribute, and a data resolution attribute. Unlike the processing module metadata **161**, the input metadata **60** associated with sensing data can at least partially change every moment. For example, the outlier frequency that may be contained in the input metadata **60** is not predefined at the shipment of the real sensor **12** but can change with the continuous operation of the real sensor **12**. For example, the outlier frequency is low immediately after the shipment when the real sensor **12** is new. However, the outlier frequency increases as the real sensor **12** is operated for a long period of time. The real sensor **12** monitors, for example, whether the sensing data falls in a range of outliers, and sequentially updates the outlier frequency within a predetermined period. The updated outlier frequency is associated with the sensing data as the input metadata **60**. In addition to the outlier frequency, for example, other attributes such as the data dropout frequency, the sensor state attribute, and the sensor maintenance history attribute can change every moment.

Referring back to FIG. **8**, the data filtering unit **121** divides the input data output from the real sensor **12** into sensing data and input metadata. The sensing data is output to the processing module **150**. The input metadata is output to the metadata check unit **122**.

The metadata check unit **122** obtains, from the processing module metadata DB **160** (FIG. **5**), the processing module metadata **161** (FIG. **1**) associated with the input port that receives data. The metadata check unit **122** determines whether the sensing data satisfies the conditions of input data based on the processing module metadata **161** and the input metadata. When, for example, the attributes indicated by the input metadata satisfy the conditions indicated by the processing module metadata **161**, the metadata check unit **122** determines that the sensing data satisfies the conditions of input data.

More specifically, the metadata check unit **122** determines whether the quality of sensing data satisfies the quality conditions of input data based on the processing module metadata **161** and input metadata. When, for example, the quality attributes indicated by the input metadata satisfy the quality conditions indicated by the processing module metadata **161**, the metadata check unit **122** determines that the quality of the sensing data satisfies the quality conditions of input data.

The accident check unit **123** determines whether the input data has any accident based on metadata associated with the sensing data. When, for example, the input metadata has garbling, a probability of being an outlier higher than the outlier frequency, or a dropout frequency higher than the data dropout frequency, the accident check unit **123** determines that the input data has an accident.

The input metadata is then input into the processing module **150**. The input quality check results based on the check results of the metadata check unit **122** and the accident check unit **123** are input into the session control module **130**.

For example, the input quality check result is determined as affirmative when the quality of the sensing data is determined to satisfy the quality conditions of input data and the input data is determined to have no accident. The input quality check result is determined as negative when the quality of the sensing data is determined to fail to satisfy the quality conditions of input data or the input data is determined to have any accident.

2-3-3. Session Control Module

FIG. **10** is a diagram of the session control module **130** showing its detailed example configuration. The session control module **130** controls switching of a session between the processing module **150** and the real sensor **12**. Switching of a session between the processing module **150** and the real sensor **12** refers to switching of an input sensor for the processing module **150** to another real sensor **12**. In the example in FIG. **10**, the session control module **130** includes a switching determination unit **131**, an input candidate selection unit **132**, and a session switching unit **133**.

The switching determination unit **131** determines whether the input sensor for the processing module **150** is to be switched based on the input quality check result of the input quality check module **120**. For example, the switching determination unit **131** determines that the input sensor is not to be switched when the input quality check result is affirmative, and determines that the input sensor is to be switched when the input quality check result is negative.

When the switching determination unit **131** determines that the input sensor is to be switched, the input candidate

selection unit **132** selects any of the real sensors **12** from the input candidates registered with the input candidate DB **140** (FIG. **4**). The input candidate selection unit **132** selects, for example, a real sensor **12** having a high priority in the input candidate DB **140** among the multiple real sensors **12** associated with the input port for which the input sensor is determined to be switched. The real sensor **12** selected by the input candidate selection unit **132** is hereafter also referred to as a selected real sensor.

The session switching unit **133** switches the input sensor to the selected real sensor. More specifically, the session switching unit **133** controls the input port of the processing module **150** to switch the input sensor to the selected real sensor. The session switching unit **133** then transmits a sensor switching command to the SDTM server **200** through the communication I/F **190** to transfer data from the selected real sensor to the input port. The sensor switching command will be described in detail later.

When, for example, the quality of input data fails to satisfy the quality conditions, the input sensor can be switched to the real sensor **12** that outputs input data satisfying the quality conditions.

2-4. Example Configuration of Hardware of SDTM Server

FIG. **11** is a diagram of the SDTM server **200** showing its example hardware configuration. The SDTM server **200** according to the present embodiment is implemented by, for example, a general-purpose computer.

In the example in FIG. **11**, the SDTM server **200** includes a controller **240**, a communication I/F **260**, and a storage **250**. The components are electrically connected to one another with a bus **265**.

The controller **240** includes, for example, a CPU **242**, a RAM **244**, and a ROM **246**. The controller **240** controls each unit in accordance with the information processing to be performed.

The communication I/F **260** communicates with external devices (e.g., the virtual sensor management server **100**, the application servers **300**, and the sensor network unit **14**; refer to FIG. **2**) external to the SDTM server **200** through the Internet **15**. The communication I/F **260** includes, for example, a wired LAN module and a wireless LAN module.

The storage **250** is an auxiliary storage such as a hard disk drive or a solid-state drive. The storage **250** stores, for example, the sensor metadata DB **230** and a control program **251**.

FIG. **12** is a table showing an example sensor metadata DB **230**. Referring to FIG. **12**, the sensor metadata DB **230** manages metadata indicating the attributes of the real sensors **12** included in the sensor network unit **14** (FIG. **2**). Metadata of each real sensor **12** included in the sensor network unit **14** is registered in advance with the sensor metadata DB **230**. The sensor metadata DB **230** manages metadata for each real sensor **12**.

The sensor metadata includes, for example, basic attributes and quality attributes. The basic attributes are the basic attributes to be satisfied by the real sensor **12**, including a class, an observation target, and an installation location.

The quality attributes relate to the quality of the sensing data output from the real sensor **12**, including an outlier frequency, a data dropout frequency, and the manufacturer of the real sensor **12**. The quality attributes may further include a sensor state attribute, a sensor installation attribute, a sensor maintenance history attribute, a data specification attribute, and a data resolution attribute.

Referring back to FIG. **11**, the control program **251** is used for the SDTM server **200** and is executed by the controller **240**. For example, the input candidate search module **210** and the data flow control module **220** (FIG. **2**) may be implemented by the controller **240** executing the control program **251**. When the controller **240** executes the control program **251**, the control program **251** is loaded into the RAM **244**. The CPU **242** in the controller **240** then interprets and executes the control program **251** loaded in the RAM **244** to control each unit. Each software module implemented by the controller **240** in accordance with the control program **251** will be described.

2-5. Example Software Configuration of SDTM Server

Referring back to FIG. **2**, the controller **240** implements the input candidate search module **210** and the data flow control module **220** in the SDTM server **200**. The software modules will be described one after another.

2-5-1. Input Candidate Search Module

FIG. **13** is a diagram of the input candidate search module **210** showing its detailed example configuration. In the example in FIG. **13**, the input candidate search module **210** includes a user data catalogue obtaining unit **211**, a sensor metadata obtaining unit **212**, a provider data catalogue generator **215**, a matching unit **213**, and an input candidate obtaining unit **214**.

The user data catalogue obtaining unit **211** obtains the above user data catalogue from the virtual sensor management server **100** (input candidate management module **110**) through the communication I/F **260**.

The sensor metadata obtaining unit **212** obtains the sensor metadata **13** (FIG. **1**) associated with each real sensor **12** registered with the sensor metadata DB **230** (FIG. **12**).

The provider data catalogue generator **215** generates a provider data catalogue based on the sensor metadata **13**. The provider data catalogue is generated for each real sensor **12** registered with the sensor metadata DB **230**. The provider data catalogue lists the attributes of each provider (each real sensor **12**). The provider data catalogue contains the attributes of the real sensor **12** indicated by the sensor metadata **13**. For example, the provider data catalogue includes the above basic attributes and quality attributes.

The matching unit **213** determines whether the user data catalogue obtained by the user data catalogue obtaining unit **211** matches the provider data catalogue generated by the provider data catalogue generator **215**. When, for example, the attributes of the real sensor **12** contained in the provider data catalogue satisfy the conditions of input data output to the processing module **150** contained in the user data catalogue, their matching is successful. When the matching is successful, the real sensor **12** associated with the provider data catalogue is extracted as an input sensor candidate. When, for example, the attributes of the real sensor **12** contained in the provider data catalogue fail to satisfy the conditions of input data output to the processing module **150** contained in the user data catalogue, their matching is unsuccessful. When the matching is unsuccessful, the real sensor **12** associated with the provider data catalogue is not extracted as an input sensor candidate.

The input candidate obtaining unit **214** obtains information that can identify the real sensor **12** (real sensor information) extracted as the input sensor candidate by the matching unit **213**. The real sensor information obtained by

the input candidate obtaining unit **214** is transmitted to the virtual sensor management server **100** (input candidate management module **110**) through the communication I/F **260**.

2-5-2. Data Flow Control Module

FIG. **14** is a diagram of the data flow control module **220** showing its detailed example configuration. In the example in FIG. **14**, the data flow control module **220** includes a sensor switching command obtaining unit **221** and a data flow control command generator **222**.

The sensor switching command obtaining unit **221** obtains the above sensor switching command from the virtual sensor management server **100** (session control module **130**) through the communication I/F **260**. The sensor switching command includes, for example, real sensor information about the real sensor **12** (current real sensor **12**) that currently outputs input data to the processing module **150** and real sensor information about the switching target real sensor **12**.

The data flow control command generator **222** generates a data flow control command based on the real sensor information about the current real sensor **12** and the real sensor information about the switching target real sensor **12**. The data flow control command includes an output stop command to stop outputting input data to the processing module **150** from the current real sensor **12**, and an output start command to start outputting input data to the processing module **150** from the switching target real sensor **12**. The output stop command is transmitted to the current real sensor **12** through the communication I/F **260**. When the output stop command is transmitted to the current real sensor **12**, the output of sensing data from the current real sensor **12** is stopped. The output start command is transmitted to the switching target real sensor **12** through the communication I/F **260**. When, for example, the output of sensing data is allowed in response to the output start command, the switching target real sensor **12** transmits an application programming interface (API) to the virtual sensor management server **100** to establish communication with the target processing module **150**. When the virtual sensor management server **100** executes the API, the switching target real sensor **12** starts outputting sensing data to the target processing module **150**.

3. OPERATION EXAMPLES

3-1. Operation Example of Extraction of Input Candidate

FIG. **15** is a flowchart showing an example operation of the processing module **150** extracting input sensor candidates. The processing in this flowchart is performed in predetermined cycles. As described above, the input sensor candidates are extracted for each input port of the processing module **150**. The procedure will be described using one input port of one processing module **150**.

Referring to FIG. **15**, the left part of the flowchart is performed when the controller **170** operates as the input candidate management module **110**. The right part of the flowchart is performed when the controller **240** operates as the input candidate search module **210**.

Referring to the left part of FIG. **15**, the controller **170** obtains the processing module metadata **161** associated with the input port from the processing module metadata DB **160** (FIG. **5**) (step S**100**). The controller **170** generates a user data catalogue based on the obtained processing module metadata **161** (step S**110**).

The controller **170** controls the communication I/F **190** to transmit the generated user data catalogue to the SDTM server **200** (step S**120**). The controller **170** then determines whether the information indicating the input sensor candidates (real sensor information) is received from the SDTM server **200** through the communication I/F **190** (step S**130**). When determining that the real sensor information is not received (No in step S**130**), the controller **170** waits until the real sensor information is received.

Referring to the right part of FIG. **15**, the controller **240** determines whether the user data catalogue is received (step S**200**). When determining that the user data catalogue is not received (No in step S**200**), the controller **240** waits until the user data catalogue is received.

When determining that the user data catalogue is received (Yes in step S**200**), the controller **240** obtains the sensor metadata **13** of each real sensor **12** managed in the sensor metadata DB **230** (step S**210**). The controller **240** generates a provider data catalogue based on the obtained sensor metadata **13** (step S**220**).

The controller **240** extracts input sensor candidates from the multiple real sensors **12** managed in the sensor metadata DB **230** based on the obtained user data catalogue and the generated provider data catalogue (step S**230**).

When, for example, the attributes (e.g., the basic attributes and the quality attributes) listed in the provider data catalogue satisfy the conditions (e.g., the basic conditions and the quality conditions) listed in the user data catalogue, the controller **240** extracts the real sensors **12** associated with the provider data catalogue as input sensor candidates. For example, the controller **240** extracts input sensor candidates greater in number than the input ports of the processing module **150**. When, for example, the processing module **150** has three input ports, the controller **240** extracts four or more input sensor candidates.

The controller **240** controls the communication I/F **260** to transmit the extracted multiple pieces of real sensor information to the virtual sensor management server **100** (step S**240**).

Referring back to the left part of FIG. **15**, when multiple pieces of real sensor information (information indicating input sensor candidates) are received in step S**130** (Yes in step S**130**), the controller **170** prioritizes each real sensor **12** with predetermined criteria (step S**140**).

The controller **170** then updates the input candidate DB **140** in accordance with the priorities (step S**150**). In other words, the controller **170** updates the input candidate DB **140** to manage the extracted input sensor candidates in accordance with the priorities assigned to them.

Thus, the virtual sensor management server **100** and the SDTM server **200** extract input sensor candidates for the processing module **150** based on the processing module metadata **161** and the sensor metadata **13**. In other words, input sensor candidates are extracted using the conditions of input data output to the processing module **150**. Thus, the virtual sensor management server **100** and the SDTM server **200** can extract, in advance, appropriate candidates for the real sensors **12** that output the input data to the processing module **150**.

3-2. Operation Example of Checking Quality of Input Data

FIG. **16** is a flowchart showing an example operation of checking the quality of input data output to the processing

module **150**. The processing in this flowchart is performed when the controller **170** operates as the input quality check module **120** in response to input of data into the processing module **150**. As described above, the quality of input data is checked for each input port of the processing module **150**. The procedure will be described using one input port of one processing module **150**.

Referring to FIG. **16**, the controller **170** extracts input metadata from input data output to the processing module **150** (step S**300**). The controller **170** checks the extracted input metadata (step S**310**). For example, the controller **170** checks the quality of input data based on the processing module metadata **161** associated with the input port and the input metadata. For example, the controller **170** determines the quality of input data as affirmative when the quality attributes indicated by the input metadata satisfy the quality conditions indicated by the processing module metadata **161**, and determines the quality of input data as negative when the quality attributes indicated by the input metadata fail to satisfy the quality conditions indicated by the processing module metadata **161**.

The controller **170** then determines whether the input data has any accident based on the input metadata (step S**320**). For example, the controller **170** determines that the input data has an accident when the input metadata has garbling. For example, the controller **170** determines the quality of input data as negative when determining that the input data has an accident, and determines the quality of input data as affirmative when determining that the input data has no accident.

The input quality check module **120** (controller **170**) notifies the session control module **130** (controller **170**) of the input quality check result based on the determination results obtained in steps S**310** and S**320** (step S**330**). For example, the input quality check module **120** determines the input quality check result as affirmative when the quality is determined as affirmative in both steps S**310** and S**320**, and determines the input quality check result as negative when the quality is determined as negative in at least one of steps S**310** and S**320**.

As described above, in the virtual sensor management server **100**, the input metadata includes the quality attributes of input data output to the processing module **150**. The quality of input data is checked based on the input metadata. In other words, the virtual sensor management server **100** can check the quality of input data output to the processing module **150**.

3-3. Session Switching Operation Example

FIG. **17** is a flowchart showing an example operation of switching a session between the processing module **150** and the real sensor **12**. The processing in this flowchart is performed when the controller **170** operates as the session control module **130** in response to a notification of the input quality check result from the input quality check module **120**. As described above, switching the session is performed for each input port of each processing module **150**. The procedure will be described using one input port of one processing module **150**.

Referring to FIG. **17**, the controller **170** determines whether the session is to be switched based on the notified input quality check result (step S**400**). For example, the controller **170** determines that the session is not to be switched when the input quality check result is affirmative, and determines that the session is to be switched when the input quality check result is negative.

Subsequently, the controller **170** determines whether the session is determined to be switched in step S**400** (step S**410**). When the session is determined not to be switched (No in step S**410**), the controller **170** maintains the session without switching the input sensor for the processing module **150** (step S**430**).

When the session is determined to be switched (Yes in step S**410**), the controller **170** determines whether any switchable candidate is available (step S**420**). For example, the controller **170** determines whether the input candidate DB **140** manages any input sensor candidates for the relevant input port. For example, the controller **170** determines that switchable candidates are available when the input candidate DB **140** manages input sensor candidates for the relevant input port, and determines that no switchable candidate is available when the input candidate DB **140** manages no input sensor candidate for the relevant input port.

When determining that no switchable candidate is available (No in step S**420**), the controller **170** maintains the session without switching the input sensor for the processing module **150** (step S**430**). When determining that switchable candidates are available (Yes in step S**420**), the controller **170** selects one input sensor candidate (selected real sensor) from input sensor candidates managed in the input candidate DB **140** (step S**440**).

The controller **170** then performs the processing for session switching (step S**450**). For example, the controller **170** controls the input port of the processing module **150** to switch the input sensor to the selected real sensor. The controller **170** also controls the communication I/F **190** to transmit the above sensor switching command to the SDTM server **200**.

As described above, in the virtual sensor management server **100**, the input sensor is switched to another real sensor **12** when the input data output to the processing module **150** fails to satisfy the quality conditions. Thus, the virtual sensor management server **100** discontinues input of data failing to satisfy the quality conditions into the processing module **150** and can maintain the quality of input data.

In the virtual sensor management server **100**, real sensors **12** that output input data satisfying the quality conditions are extracted in advance, and the real sensor **12** that outputs input data to the processing module **150** is switched to any of the real sensors **12** extracted in advance. The virtual sensor management server **100** receives data satisfying the quality conditions from the switched real sensor **12** and can thus maintain the quality of input data output to the processing module **150**.

3-4. Data Flow Control Operation Example

FIG. **18** is a flowchart showing an example of a data flow control operation. The processing in this flowchart is performed when the controller **240** operates as the data flow control module **220** in response to a sensor switching command from the virtual sensor management server **100** through the communication I/F **260**. As described above, the data flow is controlled for each input port of each processing module **150**. The procedure will be described using one input port of one processing module **150**.

Referring to FIG. **18**, the controller **240** determines whether a sensor switching command is received from the virtual sensor management server **100** through the communication I/F **260** (step S**500**). When determining that the

sensor switching command is not received (No in step S500), the controller **240** waits until the sensor switching command is received.

When determining that the sensor switching command is received (Yes in step S500), the controller **240** generates the above data flow control command (step S510). The controller **240** transmits the generated data flow control command to, for example, the current real sensor **12** or the switching target real sensor **12** (step S520). This completes the session switching between the processing module **150** and the real sensor **12**.

4. FEATURES

As described above, the real sensor **12** outputs input metadata in the present embodiment. The input metadata includes the quality attributes of sensing data output from the real sensor **12**. The controller **170** checks the quality of the sensing data based on the input metadata output from the real sensor **12**. Thus, the virtual sensor management server **100** refers to the input metadata including the quality attributes of sensing data and can check the quality of input data output to the processing module **150**.

The processing module **150** is an example of a processing module in an aspect of the present invention, the real sensor **12** is an example of a device in an aspect of the present invention, and the input quality check module **120** is an example of a quality check apparatus in an aspect of the present invention. The sensing data is an example of input data in an aspect of the present invention. The quality attributes contained in input metadata are examples of first metadata in an aspect of the present invention. The metadata check unit **122** is an example of a first obtaining unit in an aspect of the present invention and an example of a check unit in an aspect of the present invention. The processing module metadata **161** is an example of second metadata in an aspect of the present invention. The metadata check unit **122** is an example of a second obtaining unit in an aspect of the present invention.

5. MODIFICATIONS

Although the embodiments have been described above, the present invention is not limited to these embodiments and can be modified in various manners without departing from the sprit and scope of the invention. Modifications will be described below. The modifications described below may be combined as appropriate.

5-1

In the above embodiments, input sensor candidates for the processing module **150** are extracted. Instead of input sensor candidates for the processing module **150**, for example, candidates for data sets to be input into the processing module **150** may be extracted. Each data set includes multiple pieces of data generated in advance. An example of a data set is a set of sensing data obtained in advance by observing an object for a predetermined period. A data set is stored in, for example, a storage connected to the Internet **15**.

In this case, for example, metadata indicating the attributes of each data set is managed by the SDTM server **200**. A provider data catalogue is generated based on the metadata associated with the data set. Based on the user data catalogue and the provider data catalogue, data sets satisfying the conditions of input data output to the processing module **150** are extracted. In other words, based on the processing module metadata **161** and metadata associated with each data set, candidates for data sets greater in number than the input ports of the processing module **150** are extracted from multiple data sets. Thus, an appropriate data set satisfying the conditions of input data output to the processing module **150** can be extracted.

In the above embodiments, the quality of input data output to the processing module **150** is checked. Instead of the quality of input data, for example, the quality of a data set to be input into the processing module **150** may be checked. A data set includes multiple pieces of data and metadata indicating attributes regarding the quality of the multiple pieces of data. For example, the input quality check module **120** checks the quality of a data set including the metadata based on the metadata. Thus, the quality of a data set to be input into the processing module **150** can be checked.

In the above embodiments, when the input data output to the processing module **150** fails to satisfy the quality conditions, the input sensor for the processing module **150** is switched to another real sensor **12**. Instead of switching a real sensor **12** to another, for example, a data set to be input into the processing module **150** may be switched to another data set when the input data output to the processing module **150** fails to satisfy the quality conditions.

In the above embodiments, a switching target real sensor **12** is selected from input sensor candidates extracted in advance. As described above, data sets may be extracted in advance, and a data set may be selected as a switching target. In this case, data contained in each of the multiple data set candidates extracted in advance satisfies the quality conditions of input data output to the processing module **150**.

Both the real sensors **12** and the data sets may be extracted in advance as input candidates for the processing module **150** and selected as switching targets to be input into the processing module **150**.

5-2

In the above embodiments, each input port of each processing module **150** performs a session with any of the real sensors **12**. Instead of the real sensor **12**, each input port may perform a session with, for example, a storage storing a data set or with a virtual sensor. Without performing a session with a sensor, input data output to the processing module **150** may be other than sensing data. Examples of the input data include shopping history data of each user at a shopping site and score data of each user at a game site.

5-3

In the above embodiments, the processing performed by the virtual sensor management server **100** and the SDTM server **200** may be implemented by, for example, multiple servers. In the above embodiments, the processing performed by the virtual sensor management server **100** and the SDTM server **200** may be implemented by, for example, a single server.

The invention claimed is:

1. A quality check apparatus comprising a controller configured with a control program for checking a quality of input data received from a device by the controller configured with the control program to perform operations comprising operating as a processing module, the controller receiving the input data and first metadata indicating an attribute regarding the quality of the input data on a first input port of the controller functioning as the processing

module, the controller configured with the control program to perform operations further comprising:

generating, based on at least one piece of the input data, output data different from the at least one piece of input data,

obtaining the first metadata from the device;

obtaining second metadata associated with the first input port of the controller operating as the processing module, the second metadata indicating a condition regarding the quality of the input data;

checking the quality of the input data based on the first metadata and the second metadata by comparing the first metadata and the second metadata and determining whether the attribute regarding the quality of the input data satisfies the condition regarding the quality of the input data; and

switching to a second input port of the controller operating as the processing module to receive input data and first metadata based on determining that the attribute regarding the quality of the input data fails to satisfy the condition.

2. The quality check apparatus according to claim **1**, wherein

the device comprises a sensor, and

the input data comprises sensing data generated by the sensor.

3. The quality check apparatus according to claim **1**, wherein

the controller is configured with the control program to perform operations such that operating as the processing module comprises generating the output data based on a plurality of pieces of the input data.

4. The quality check apparatus according to claim **1**, wherein

the controller is configured with the control program to perform operations such that switching to the second input port of the processing module comprises switching from receiving, from the device, the input data on the first input port of the processing module to receiving, from a second device, input data on the second input port.

5. The quality check apparatus according to claim **1**, wherein

the controller configured with the control program to perform operations comprising operation as the processing module and the device from which the input data is received by the processing module form a virtual sensor.

6. A quality check apparatus comprising a controller configured with a control program for checking a quality of at least one data set to be received into a first input port of the controller configured with the control program to perform operations comprising operating a processing module, the at least one data set comprising a plurality of pieces of data and first metadata indicating an attribute regarding a quality of each of the plurality of pieces of data, the controller configured with the control program to perform operations further comprising:

generating, based on at least one piece of input data, output data different from the at least one piece of input data when the at least one data set is input,

obtaining the first metadata from the device;

obtaining second metadata associated with the first input port of the controller operating as the processing module, the second metadata indicating a condition regarding the quality of the input data;

checking the quality of the at least one data set based on the first metadata and the second metadata by comparing the first metadata and the second metadata and determining whether the attribute regarding the quality of the input data satisfies the condition regarding the quality of the input data; and

switching to a second input port of the controller operating as the processing module to receive input data and first metadata based on determining that the attribute regarding the quality of the input data fails to satisfy the condition.

7. A quality check method for checking a quality of input data received from a device by a computer functioning as a processing module,

the computer receiving the input data and first metadata indicating an attribute regarding the quality of the input data to a first input port of the computer functioning as the processing module, the quality check method comprising:

generating, based on at least one piece of the input data, output data different from the at least on piece of input data;

obtaining the first metadata from the device;

obtaining second metadata associated with the first input port of the computer functioning as the processing module, the second metadata indicating a condition regarding the quality of the input data;

checking the quality of the input data based on the first metadata and the second metadata by comparing the first metadata and the second metadata and determining whether the attribute regarding the quality of the input data satisfies the condition regarding the quality of the input data; and

switching to a second input port of the computer functioning as the processing module to receive input data and first metadata based on determining that the attribute regarding the quality of the input data fails to satisfy the condition.

8. A non-transitory computer-readable storage medium storing a program, which when read and executed, causing a computer to implement checking a quality of input data received from a device by the computer functioning as a processing module, which receives the input data and first metadata indicating an attribute regarding the quality of the input data on a first port of the computer functioning as the processing module, the program causing the computer to perform operations comprising:

generating, based on at least one piece of the input data, output data different from the at least one piece of input data,

obtaining the first metadata from the device;

obtaining second metadata associated with the first input port of the computer functioning as the processing module, the second metadata indicating a condition regarding the quality of the input data;

checking the quality of the input data based on the first metadata and the second metadata by comparing the first metadata and the second metadata and determining whether the attribute regarding the quality of the input data satisfies the condition regarding the quality of the input data; and

switching to a second input port of the computer functioning as the processing module to receive input data and first metadata based on determining that the attribute regarding the quality of the input data fails to satisfy the condition.

9. The quality check apparatus according to claim 2, wherein

the controller is configured with the control program to perform operations such that generating the output data comprises generating the output data based on a plurality of pieces of the input data.

10. The quality check apparatus according to claim 2, wherein

the controller is configured with the control program to perform operations such that switching to a second input port of the controller operating as the processing module comprises switching from receiving, from the device, the input data on the first input port of the processing module to receiving, from a second device, input data on the second input port.

11. The quality check apparatus according to claim 2, wherein

the controller configured with the control program to perform operations comprising operation as the processing module and the device from which the input data is received by the processing module form a virtual sensor.

12. The quality check apparatus according to claim 3, wherein

the controller is configured with the control program to perform operations such that switching to a second input port of the processing module comprises switching from receiving, from the device, the input data on the first input port of the processing module to receiving, from a second device, input data on the second input port.

13. The quality check apparatus according to claim 3, wherein

the controller configured with the control program to perform operations comprising operation as the processing module and the device from which the input data is received by the processing module form a virtual sensor.

14. The quality check apparatus according to claim 4, wherein

the controller configured with the control program to perform operations comprising operation as the processing module and the device from which the input data is received by the processing module form a virtual sensor.

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